High-Aperture-Efficiency Horn Antenna

Major design features are a hard (in the electromagnetic sense) boundary and a cosine taper.

NASA's Jet Propulsion Laboratory, Pasadena, California

A horn antenna (see Figure 1) has been developed to satisfy requirements specific to its use as an essential component of a high-efficiency Ka-band amplifier: The combination of the horn antenna and an associated microstrip-patch antenna array is required to function as a spatial power divider that feeds 25 monolithic microwave integrated-circuit (MMIC) power amplifiers. The foregoing requirement translates to, among other things, a further requirement that the horn produce a uniform, vertically polarized electromagnetic field in its aperture in order to feed the microstrip patches identically so that the MMICs can operate at maximum efficiency.

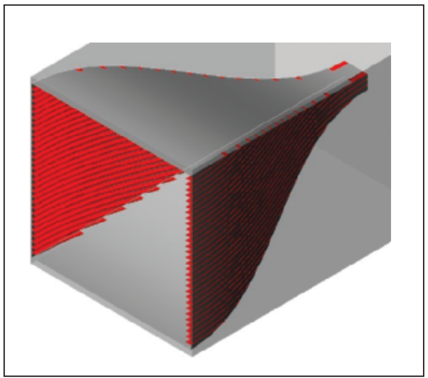


Figure 1. This **Horn Antenna** features cosine-tapered corrugation that imparts desired impedance characteristics.

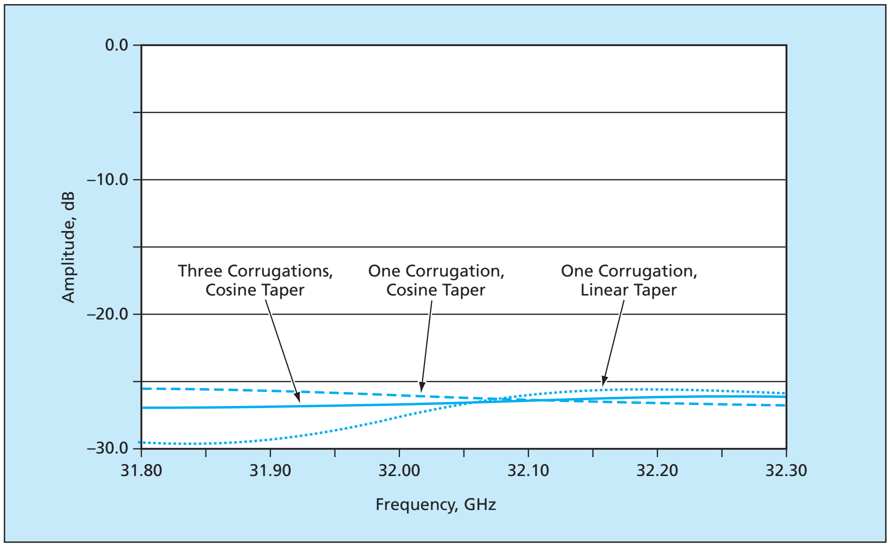


Figure 2. The **Computed Input Reflection Coefficient** in the desired electromagnetic mode was found to be more nearly constant with frequency for the cosine-taper designs than for the linear-taper design. The maximum depth of the taper [73 mils (1.85 mm)] is the same in all three designs.

The horn is fed from a square waveguide of 5.9436-mm-square cross section via a transition piece. The horn features cosine-tapered, dielectric-filled longitudinal corrugations in its vertical walls to create a hard boundary condition: This aspect of the horn design causes the field in the horn aperture to be substantially vertically polarized and to be nearly uniform in amplitude and phase.

As used here, "cosine-tapered" signifies that the depth of the corrugations is a cosine function of distance along the horn. Preliminary results of finite-element simulations of performance have shown that by virtue of the cosine taper the impedance response of this horn can be expected to be better than has been achieved previously in a similar horn having linearly tapered dielectric-filled longitudinal corrugations.

It is possible to create a hard boundary condition by use of a single dielectric-filled corrugation in each affected wall, but better results can be obtained with more corrugations. Simulations were performed for a one- and a three-corrugation cosine-taper design. For comparison, a simulation was also performed for a linear-taper design (see Figure 2). The three-corrugation design was chosen to minimize the cost of fabrication while still affording acceptably high performance. Future designs using more corrugations per wavelength are expected to provide better field responses and, hence, greater aperture efficiencies.

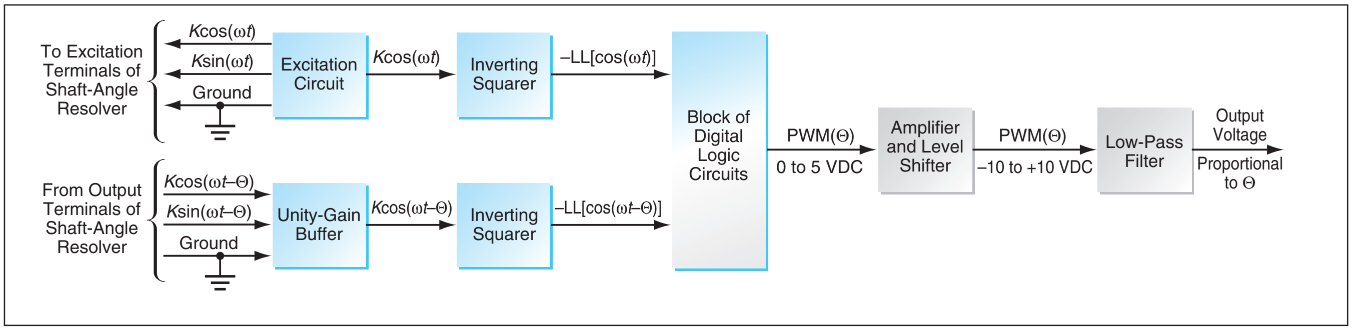
This work was done by Wesley Pickens, Daniel Hoppe, Larry Epp, and Abdur Kahn of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1). NPO-40023*

Full-Circle Resolver-to-Linear-Analog Converter

This circuit costs less and is less susceptible to error.

Marshall Space Flight Center, Alabama

A circuit generates sinusoidal excitation signals for a shaft-angle resolver and, like the arctangent circuit described in the preceding article, generates an analog voltage proportional to the shaft angle. The disadvantages of the circuit described in the preceding article arise from the fact that it must be made from precise analog subcircuits, including a functional block capable of implementing some trigonometric identities; this circuitry tends to be expensive, sensitive to noise, and susceptible to errors caused by temperature-induced drifts and imprecise matching of



The **Resolver-to-Linear-Analog Converter** is depicted here in simplified form. This circuit provides excitation for a shaft-angle resolver and generates a DC output voltage proportional to the shaft angle, Θ.

gains and phases. These disadvantages are overcome by the design of the present circuit.

The present circuit (see figure) includes an excitation circuit, which generates signals $K\sin(\omega t)$ and $K\cos(\omega t)$ [where K is an amplitude, ω denotes $2\pi \times$ a carrier frequency (the design value of which is 10 kHz), and t denotes time]. These signals are applied to the excitation terminals of a shaft-angle resolver, causing the resolver to put out signals $C\sin(\omega t - \Theta)$ and $C\cos(\omega t - \Theta)$. The cosine excitation signal and the cosine resolver output signal are processed through inverting comparator circuits, which are configured to function as inverting squarers, to obtain logic-level or square-wave signals $-\mathrm{LL}[\cos(\omega t)]$ and $-\mathrm{LL}[\cos(\omega t - \Theta)]$, respectively. These signals are fed as inputs to a block containing digital logic circuits that effectively measure the phase difference (which equals Θ between the two logic-level signals). The output of this block is a pulse-width-modulated signal, PWM(Θ), the time-averaged value of which ranges from 0 to 5 VDC as Θ ranges from –180 to +180°.

PWM(Θ) is fed to a block of amplifying and level-shifting circuitry, which converts the input PWM waveform to an output waveform that switches between precise reference voltage levels of +10 and –10 V. This waveform is processed by a two-pole, low-pass filter, which removes the carrier-frequency component. The final output signal is a DC potential, proportional to Θ that ranges continuously from –10 V at Θ = –180° to +10 V at Θ = +180°.

This work was done by Dean C. Alhorn, Dennis A. Smith, and David E. Howard of **Marshall Space Flight Center**.

This invention has been patented by NASA (U.S. Patent No. 6,104,328). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at (256) 544-5226 or sammy.a.nabors@nasa.gov. Refer to MFS-31237.

Continuous, Full-Circle Arctangent Circuit

The discontinuity of the tangent function at 90° causes no trouble.

Marshall Space Flight Center, Alabama

A circuit generates an analog voltage proportional to an angle, in response to two sinusoidal input voltages having magnitudes proportional to the sine and cosine of the angle, respectively. That is to say, given input voltages proportional to $\sin(\omega t)\sin(\Theta)$ and $\sin(\omega t)\cos(\Theta)$ [where Θ denotes the angle, ω denotes $2\pi \times$ a carrier frequency, and t denotes time], the circuit generates a steady voltage proportional to Θ. The output voltage varies continuously from its minimum to its maximum value as Θ varies from –180° to 180°. While the circuit could accept input modulated sine and cosine signals from any source, it must be noted that such signals are typical of the outputs of shaft-angle resolvers in electromagnetic actuators used to measure and control shaft angles for diverse purposes like aiming scientific instruments and adjusting valve openings.

In effect, the circuit is an analog computer that calculates the arctangent of the ratio between the sine and cosine signals. The full-circle angular range of this arctangent circuit stands in contrast to the range of prior analog arctangent circuits, which is from slightly greater than –90° to slightly less than +90°. Moreover, for applications in which continuous variation of output is preferred to discrete increments of output, this circuit offers a clear advantage over resolver-to-digital integrated circuits.

The figure depicts the main functional blocks of the arctangent circuit. In addition to the aforementioned input signals proportional to $\sin(\omega t)\sin(\Theta)$ and $\sin(\omega t)\cos(\Theta)$, the circuit receives the carrier signal proportional to $\sin(\omega t)$ as an auxiliary input. The carrier signal is fed to a squarer (block 7) to obtain an output square-wave or logic-level signal, $\mathrm{LL}[\sin(\omega t)]$. The demodulator (block 1) uses $\mathrm{LL}[\sin(\omega t)]$ to demodulate input signal $\sin(\omega t)\cos(\Theta)$, generating an output proportional to $\cos(\Theta)$.

The carrier signal $\sin(\omega t)$ is also fed to an integrator and inverter (block 8) to obtain a signal proportional to $\cos(\omega t)$. The $\cos(\omega t)$ signal is fed to a squarer (block 9) to obtain a logic-level signal $\mathrm{LL}[\cos(\omega t)]$. The $\cos(\Theta)$ and $\cos(\omega t)$ signals are fed to a multiplier (block 2) to obtain a signal proportional to $\cos(\Theta)\cos(\omega t)$. This signal and the input $\sin(\omega t)\sin(\Theta)$ signal are fed to an inverter and adder (block 3) to obtain a signal proportional to $-[\cos(\Theta)\cos(\omega t) + \sin(\Theta)\sin(\omega t)]$, which, by trigonometric identity, equals $-\cos(\omega t - \Theta)$. This signal is processed by an inverter and squarer (block 4) to obtain a logic-level signal $\mathrm{LL}[\cos(\omega t - \Theta)]$.

The signal $\mathrm{LL}[\cos(\omega t)]$ from block 9 and the signal $\mathrm{LL}[\cos(\omega t - \Theta)]$ from block 4 have the same frequency but differ in phase by Θ. These signals are fed